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ABSTRACT

There is virtually universal agreement on the need to strengthen science education at all levels in Ohio. Not only must the state be able to produce more and better scientists, but it is increasingly important for all citizens to become knowledgeable about scientific issues and analysis. This report presents the conclusions and recommendations about the need for supplies and equipment in high school chemistry and physics programs. Information for this study came from three principal sources: site visits to high schools, a mail survey of high schools, and a telephone survey of college and university faculty. In addition, recent high school graduates enrolled in college programs were polled. Chapter 1 discusses general issues in science education and the methods used in this study. Chapter 2 describes the physics of chemistry curricula in use in Ohio. Chapter 3 describes the supplies and equipment actually available in high school science classrooms and laboratories. Chapter 4 discusses the supporting resources available to high school academic courses including libraries, safety equipment, and chemical storage and disposal. Recommendations for improvements in the situations in Ohio high schools are provided in each chapter. Appendices include: a copy of the surveys used in this study and the telephone survey protocol; lists of physics and chemistry equipment; lists of safety equipment; and a table of typical lab fees charged for high school chemistry and physics. (CW)

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HIGH SCHOOL CHEMISTRY AND PHYSICS: SUPPLY AND EQUIPMENT ISSUES

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July 1990

HIGH SCHOOL CHEMISTRY AND PHYSICS: SUPPLY AND EQUIPMENT ISSUES

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EXECUTIVE SUMMARY

There is virtually universal agreement on the need to strengthen science education at all levels in Ohio. Not only must the state be able to produce more and better scientists, but it is increasingly important for all citizens to become more knowledgeable about scientific issues and analysis.

This is a report of the Legislative Office of Education Oversight to the Legislative Committee on Education Oversight, describing our conclusions and recommendations about the need for supplies and equipment in high school chemistry and physics programs. ***Conclusions and recommendations in this report are those of the LOEO staff and do not necessarily reflect the views of the Committee or any of its members.***

Information for this study came from three principal sources: site visits to ten high schools in eight districts across Ohio; a mail survey of 182 high schools throughout the state, to which about 67 percent responded; and a telephone survey of college and university faculty in which we asked their opinions about what kinds of high school preparation were most likely to lead to success in postsecondary science courses. In addition, we contacted 45 college students who were recent graduates of the high schools we visited to ask how well they had been prepared for their postsecondary science courses. LOEO staff also interviewed a number of scientists and science teachers and reviewed professional literature.

CHAPTER II - WHAT MATERIALS SHOULD BE AVAILABLE?

Chapter II describes the physics and chemistry curricula in use in Ohio, and points out differences between traditional curricula and two innovative courses, called Conceptual Physics and Chemistry in the Community.

It would be possible to develop a general list of supplies and equipment that should be available and used in all classrooms. However, the precise list of items for each school or teacher depends very much upon the textbook and curriculum being used. While some concepts can be conveyed quite well using makeshift or older equipment, computers have considerable potential for improving science instruction.

LOEO recommends that:

* **the General Assembly request the Ohio Department of Education to adopt model curricula with minimum equipment lists for at least high school physics and chemistry;**

* **each district and school study its supply and equipment inventory and develop a formal acquisition and replacement schedule; and**

* **each district and school prepare a plan for expanding the role of computers in science instruction.**

CHAPTER III - WHAT MATERIALS ARE AVAILABLE?

Chapter III describes the supplies and equipment actually available in high schools. As discovered through our surveys and field visits, there are disparities across and within districts as to the availability of physics and chemistry equipment. Reasons for the differences vary, but generally are attributable to local conditions, preferences, and budgets. Many individual classroom teachers show ingenuity in teaching around deficiencies.

There were two common themes among the schools. There appear to be more shortages in physics than in chemistry. In addition, the majority of chemistry and physics programs surveyed or visited are not equipped with computers and appropriate software.

LOEO recommends that:

* **every district ensure that each high school has at least basic instructional materials before providing more advanced or modern equipment to any school;**

* **each school and district identify items of equipment for which private donations or foundation or other funds might be available; and**

* **the General Assembly request the Ohio Department of Education to identify any state laws or regulations that may impede such grants or donations.**

CHAPTER IV - RELATED RESOURCES

For any academic course, some supporting resources should be available. For example, the school library should acquire books and periodicals that allow students to do research or satisfy curiosity about the subject. School library facilities appear to be generally adequate, in the opinion of science teachers.

In lab-based science courses, there is a special need for safety equipment. At least 29 percent of chemistry teachers surveyed reported that they do not have adequate safety equipment.

LOEO recommends that:

* **safety needs be addressed and given the highest priority as schools and districts prepare the materials acquisition and replacement schedules as recommended in Chapter II;**

* **the General Assembly instruct the Ohio Department of Education to include safety equipment and procedures in its model curricula for science instruction; and**

* **each high school's need for safety equipment and procedures be continually assessed by someone other than classroom teachers. State and local fire and building officials should be able to provide advice and assistance with this.**

Many schools do not have any method of storing chemicals or of disposing of old, outdated, and, in many cases, dangerous chemicals. Seven of the 10 schools we visited and almost half of the 123 responding to our survey reported inadequate storage or disposal of chemicals.

According to an official at the Ohio Environmental Protection Agency (EPA), many Ohio schools are likely to be in violation of the hazardous waste laws. There are federal and state laws and rules and training required by the Occupational Safety and Health Administration (OSHA) regarding the storage of chemicals, handling and disposal of waste. However, "the word is not getting out to the schools, especially to the vocational schools," he said. "There are problems sitting there just waiting to happen." Although many of the schools are classified only as small quantity waste generators, there are many regulations with which they are to comply.

LOEO recommends that:

* **the General Assembly immediately require the Ohio Department of Education to adopt a policy which assures adherence to the Ohio hazardous waste rules and Ohio EPA procedures governing storage and disposal of hazardous chemicals. School districts should ascertain that their inventory and storage of chemicals is in compliance with OSHA and EPA requirements;**

* the Ohio Department of Education, in consultation with the EPA and other appropriate state agencies, determine whether a short-term state program is needed to aid local schools in disposing of current supplies of hazardous materials; and

* each district have procedures requiring teachers and principals to determine whether substitute materials or computer simulation can demonstrate a principle without the need for hazardous chemicals.

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CHAPTER I

INTRODUCTION

The Legislative Office of Education Oversight (LOEO) serves as staff to the Legislative Committee on Education Oversight. Created by the Ohio General Assembly in 1989, the Office is to conduct studies of education-related activities funded wholly or in part by the state of Ohio. This report concerns supplies and equipment needs for teaching chemistry and physics in Ohio's public high schools.

This is a report of the LOEO to the Legislative Committee on Education Oversight. ***Conclusions and recommendations in this report are those of the LOEO staff and do not necessarily reflect the views of the Committee or any of its members.***

Issues in Science Instruction

Business leaders, educators, consumer groups and public officials continue to warn that Ohio must improve its science education if the state is to be competitive in a technology-based world economy. The Ohio Science and Technology Commission states, in its June 1990 final report, "The frontier today. . . is a fast-moving and competitive global economy, where success is measured by the ability to innovate. Knowledge--embodied in skilled and well equipped engineers, teachers, workers, and managers--is the most valuable resource."

It is not only future scientists who need secondary science courses of high quality. Science and technology play ever more important roles in all areas of modern life. Government, business management, manufacturing, health care, social services--even arts and humanities--are increasingly dependent on practitioners who can understand and apply scientific principles.

Even at home, people must be conversant with scientific principles to make decisions: Consumers must evaluate the conflicting health claims of various products; citizens must decide whether to vote for a levy for landfill construction; parents must assess the education their children are receiving. According to a 1988 report of the Ohio Department of Education:

> Although there must be a cadre of skilled professionals to deal with developing and applying scientific knowledge, there must also be a broad-based, scientifically literate citizenry that can respond to the scientific implications of social and technological issues. Solving tomorrow's problems requires understanding of the underlying scientific principles. A scientifically literate

> citizenry is essential for responding to social and technological issues and problems . . . .

Elements in science instruction

Several elements must come together for effective science instruction to occur in high school. First, there must be enough students who are interested in taking science courses. This is a general problem, and several studies have documented specific deficiencies in the numbers of females and minority students who are attracted to science courses. Students must also come adequately prepared with previous science courses, mathematical skills, and general practice in problem-solving.

There must be a sufficient supply of teachers with thorough up-to-date knowledge about the principles they are teaching. Teachers must also have classroom skills, and preferably enthusiasm both for students and for the subject matter.

The science curriculum and textbooks must be sufficiently demanding that students actually learn scientific principles. On the other hand, the American Association for the Advancement of Science's "Project 2061" report suggests that curriculum and textbooks that are too forbidding enhance the belief that science is a topic only for the few. The number and type of books and magazines in school libraries should also support what is being taught in the classroom.

Instructional supplies and equipment

Besides students, teachers, and textbooks, effective science instruction also requires a certain amount of supplies and equipment. This is because laboratory experience is crucial to learning science. In the high schools responding to our survey, approximately 91 percent of both physics and chemistry classes spent at least two days a month in lab; about 20 percent of both classes spent at least two days a week. A student we interviewed said:

> When you do it, it is much more memorable. When you actually do it, it proves that what you are reading is really happening. A few more demonstrations in chemistry and physics would have made things more interesting and memorable.

In trying to determine the amount and kind of materials needed, however, LOEO did not find much previous research on such questions as: Which materials are basic and which are frills? What substitutions can be made without impairing quality? When can a demonstration by the teacher be as effective as active

manipulation by students? How up-to-date must pieces of equipment be? This study addresses some of these issues.

In addition, there are particular safety concerns that arise in science classes. Materials and equipment used in science instruction may be dangerous, either mechanically or chemically. Supplies and equipment to prevent and respond to injury, as well as methods of storage and disposal of hazardous materials, are therefore of considerable importance in assessing a high school science program.

Scope and Method

The subject of this study is supplies and equipment used in high school science teaching. Because of limitations of time and staff, LOEO decided to focus the study on basic high school chemistry and physics courses. Biology and general science courses were excluded because of these restrictions. More advanced or specialized courses were excluded because of time and staff limitations, and also because not all schools offer them. We are reasonably confident, however, that at least the overall thrust of this study--and probably many of its findings and conclusions--can be generalized or adapted to other science courses.

Methods

In designing this study, LOEO staff reviewed academic and professional literature and interviewed scientists and science teachers. Data for the study came primarily from four sources. LOEO staff visited ten high schools in eight districts across the state, selected to represent a cross-section of urban and rural districts and a range of economic and financial situations. The districts and schools were promised confidentiality and are not named in this study except with their permission.

At each school, we met with the principal, physics and chemistry instructors, and students. We inspected laboratory facilities and checked for the presence of various supplies and pieces of instructional and safety equipment. We also looked for science-related publications and books in each school's library.

A second source of information was surveys mailed to the principals of 182 Ohio public high schools. Each principal received two surveys, one on chemistry and one on physics; the survey instruments are included as Appendix I-A to this report. Schools were selected randomly from a list of all public high schools in the state, except that every high school in the following districts received the surveys: Akron, Canton, Cincinnati, Cleveland, Columbus, Dayton, Toledo, and Youngstown. We received returns of 123 chemistry surveys (68%) and 118 physics surveys (65%).

Review of nonrespondents did not disclose any systematic pattern that would bias results. We also found that survey results

tended to be highly consistent with findings from our site visits. This reinforced our confidence in both the site visits and the surveys as sources of reliable information, which can probably be generalized, at least broadly, to the statewide situation.

The third major source of information was a telephone survey of chemistry and physics faculty members at 12 public colleges and universities in Ohio. The postsecondary institutions selected were those closest to the high schools we visited, although we did not try to make any direct analytic link between programs at specific high schools and college faculty's responses. Survey instruments are included as Appendix I-B.

To gain some idea of whether students at our selected high schools felt prepared for postsecondary science courses, we telephoned several recent graduates of each who were attending a postsecondary institution. The students' names were given to us by their high schools, and so were not random. A copy of the questions we asked them is included as Appendix I-C.

We began with a list of 150 students, but were able to contact only 45. For one high school, we could locate only one student. One district refused to cooperate, and another did not send a list after agreeing to do so.

LOEO appreciates the assistance and cooperation we received in conducting this study. We received valuable advice and help from Mr. Lynn Elfner of the Ohio Academy of Science; Dr. Robert Howe of Educational Resources Information Center; Mr. Dave Weaner of Westerville North High School; Dr. Neville Reay of Ohio State University; and many others. We especially appreciate those schools and districts that allowed us to visit them, and the school principals and teachers who returned our surveys.

Organization of the report

Chapter II of this report discusses ways in which a basic list of instructional supplies and equipment for high school chemistry and physics might be developed. Chapter III assesses the materials actually available in Ohio high schools, compared to the inventories described in Chapter II. Chapter IV considers the related resources needed for science teaching--library holdings, safety equipment, and provisions for storage and disposal of hazardous materials--and briefly discusses matters not directly related to supplies and equipment that arose during our study. Each chapter contains LOEO's recommendations to the General Assembly and to state and local school authorities. ***These are staff recommendations, and members of the Legislative Committee on Education Oversight may or may not agree with any of them.***

CHAPTER II

WHAT MATERIALS SHOULD BE AVAILABLE?

This chapter attempts to identify the basic supply and equipment needs of high school physics and chemistry laboratories. For this purpose, we conducted interviews with scientists and science teachers and reviewed academic and professional literature. We also relied on data gathered through our field visits and surveys.

Findings

The precise "shopping list" of each school, district, and even individual instructor depends on the particular textbook and curriculum adopted, and on the interests and abilities of the particular classroom teacher. This is especially true because there are no specifications for an acceptable level of supplies and equipment for a high school science program. It is also apparent that computers have considerable potential for improving instruction in high school physics and chemistry.

Differences Between Chemistry and Physics

In discussing chemistry and physics instructional materials, it is useful to keep in mind a few key differences in the nature of the supplies and equipment each uses. LOEO believes that despite these differences, our study's findings and recommendations are similar for both subjects.

Age of supplies and equipment

The age of supplies and equipment can be relevant in both subjects, although in different ways. Old chemicals, for example, may become either inert or unstable; old pulleys do not.

On the other hand, the visibility of technological change is more pronounced in physics. This means that older-looking physics equipment may turn students away from physics or discourage teachers from using the equipment, even though it is perfectly serviceable for experiments and instruction. A high school physics teacher, whose equipment was generally about 25 years old, said some of his students told him his lab looked like the set for a Frankenstein movie. A university physicist said:

> I think you have to have a "hook" to get students interested. You may not need fiber optics or lasers, but that's the stuff that kids see around them, even the kids that aren't interested in science. That's the sexy stuff that gets them into the classroom. Every piece of equipment doesn't have to be the most modern, but they have to see something in that science room that they recognize as being interesting.

Purchase price

In general, chemistry uses more low-cost, disposable items, such as chemicals and glassware, than does physics. Physics equipment, while more expensive initially, is often more durable.

Measurement equipment used by both courses can be expensive if state-of-the-art gear is sought. Newer measurement equipment is likely to be more precise, as well as more attractive and easier to use. It is questionable that the additional precision in itself is necessary for science instruction at the high school level. However, newer equipment has the potential to save time in teacher preparation for labs, as well as the potential to save time during laboratory sessions.

Safety

More elaborate safety equipment may be needed for chemistry than for physics. Most of the hazards in a physics class are mechanical--pieces of equipment flying up or breaking off, for instance, may cause eye damage and similar injuries. Thus, safety goggles and first-aid kits are examples of safety equipment that might be found in a physics area. For chemistry, these items are supplemented by fume hoods, emergency showers, and other devices related to chemical hazards.

Physics and Chemistry Curricula

The Ohio Department of Education does not specify what should be included in local schools' science curricula or the equipment and material needed to teach specific courses. The current state standards require that:

* natural science be taught at some point between kindergarten and 12th grade;
* a unit on conservation of natural resources be included;
* a high school offer four science courses, including at least two laboratory courses;
* a student take one science course to graduate from high school; and

* a school have the materials necessary to teach the topics contained in its approved course of study.

The science supplies and equipment needed by a particular teacher are largely determined by the choice of curriculum and textbooks made at the local level. Each textbook and its accompanying laboratory manual has a different collection of experiments that may use different pieces of equipment. The quantity of supplies and equipment needed also depends on whether a principle is to be illustrated by a teacher demonstration (in which case only one set of materials is enough) or by hands-on manipulation by students (for which multiple sets of materials are needed).

Most high school chemistry and physics instruction in Ohio follows a traditional model which presents the subject in a relatively abstract way and emphasizes quantitative and mathematical skills. In both chemistry and physics, alternative curricula have been developed that are intended to introduce students to the basic scientific principles through hands-on experiences, using everyday supplies and equipment. "Chemistry in the Community" ("ChemCom") was developed by the American Chemical Society, with financial support from the National Science Foundation and others. The American Chemical Society says ChemCom is designed to help students:

* realize the importance of chemistry in their personal and professional lives;

* use chemistry's principles "to think more intelligently about current issues. . . that involve science and technology"; and

* become aware of both the potential and the limitations of science and technology.

"Conceptual Physics," a similar program in physics, is described by its author as designed for both the science and the "non-science" student, and as a way to allow students to study science even if they are afraid of mathematics.

Physics curriculum

Most high school physics classes in Ohio appear to follow the traditional curriculum. Only 4.2 percent of the schools responding to our survey offer Conceptual Physics, and all of them also offer a traditional physics course.

Although the material in the traditional and Conceptual Physics courses is fundamentally the same, the approaches to teaching students are different. In the traditional text, the authors of the book state that "Physics often uses mathematics as its language . . . . Equations and graphs are both means of expressing relationships among variables."

The author of Conceptual Physics writes in the introduction, "You can't enjoy a game unless you first know the rules. . . . To help you learn about and comprehend nature's rules, physics is treated 'conceptually' rather than mathematically in this book. Physics concepts are in English, with equations as 'guides to thinking' rather than recipes for algebraic problem solving."

The traditional physics curriculum relies to a large extent on teaching students the formulas that describe basic physical relationships, which are presented predominately as abstractions. For example, in one of the traditional textbooks, momentum is defined as "a vector quantity that has the same direction as the velocity of the body." Contrast this more abstract definition with the Conceptual Physics definition: "The idea of inertia in motion is 'momentum,' which refers to moving things."

The organization of the textbooks demonstrates the difference in approaches to physics. The traditional text's first four chapters are titled:

1. Physics: A Mathematical Science
2. Mathematical Relationships
3. Motion in a Straight Line
4. Graphical Analysis of Motion

The Conceptual Physics text organizes its chapters into six units. The first four chapters in Unit I are titled:

1. About Science
2. Motion
3. Newton's First Law of Motion--Inertia
4. Newton's Second Law of Motion--Force and Acceleration

Experiments and demonstrations associated with a traditional physics curriculum are likely to involve single-purpose, scientific-looking apparatus. There is an emphasis on mathematical precision. After the introduction of momentum in the traditional text, a good part of the chapter is spent on calculating momentum and teaching formulas for related computations.

In contrast, Conceptual Physics introduces the formulas related to momentum, and then emphasizes how momentum acts in everyday situations. For example, students are asked to consider the difference in momentum between a truck and a roller skate moving down a hill at the same speed, and between a car hitting a concrete wall or a haystack. As the text says, this approach

encourages ". . . comprehension now, and if computation follows later (in follow-up courses), it will be with understanding!"

Physics materials

This section considers the basic "shopping list" for an introductory high school physics class. Information came from professional and academic literature, from our mail surveys, and from our field visits.

Although the state does not specify the content of the science curriculum or a list of equipment, the Ohio Department of Education has prepared some technical assistance materials, and LOEO used those in preparing this report.

Teachers were asked to identify basic equipment and supplies that they needed and those they wished they had. High school physics teachers were likely to list as basic equipment needs such items as oscilloscopes, wave tanks, air tracks, and lasers.

Appendix II-A shows a list of instructional equipment that appears in the teacher's editions of both a traditional physics text and Conceptual Physics. It is therefore not a complete list for either curriculum. We used it only to form a general idea of basic equipment needs and availability. In our site visits, we looked for these items, or close substitutes, in every high school physics department.

Teachers' categorization of individual equipment items reflect the disparity of physics supplies found in different schools. Items listed by some teachers as basic needs were listed by others on a wish list. However, as shown in Exhibit II-1, the most common item on their wish lists was computers with software.

Exhibit II-1

Physics Wish List

EQUIPMENT	NUMBER OF RESPONSES
Computers or software	62
Laser	26
Optics equipment	19
Air track and accessories	15
Electronic equipment	11
Oscilloscopes, dual trace	10

Physics teachers responding to our mail survey believed they could teach a number of key concepts more effectively if they had additional equipment or newer equipment. The most frequently mentioned were electronics, electricity, light, and optics. College physics professors also emphasized that high school physics students needed to be familiar with equipment related to these same concepts.

Familiarity with specific pieces of physics equipment, however, was not the most important predictor of success in college science courses. Instead, a good mathematical background was seen as more important than learning physics principles or working with physics equipment. When asked what was the best predictor of success in postsecondary chemistry and physics, the science department head at one college said, "Math, math, and math. The rest will follow."

Chemistry curricula

As in physics, most high school chemistry classes in Ohio appear to follow the traditional curriculum. Only 4.9 percent of the schools responding to our survey were offering ChemCom, and all of them were also offering traditional chemistry.

The traditional chemistry curriculum relies to a large extent on teaching students chemical theories and concepts with quantitative problems. Examples of principles in traditional texts are more likely to be or appear abstract and related only to laboratory phenomena. A look at the organization of the text reveals these chapter titles:

1. Nature, Chemistry, and You
2. Measuring and Calculating
3. Matter
4. Chemical Formulas
5. The Mole

In contrast, ChemCom's text and approach is more focused on the actual application of chemistry in our world today. The preface in the textbook describes chemistry as "an intimate part of everyone's life," and defines it as "the study of the substances in our world . . ." ChemCom's table of organization includes such chapter titles as:

1. The Quality of Our Water
2. A Look at Water and Its Contaminants
3. Investigating the Cause of the Fish Kill
4. Water Purification and Treatment
5. Putting it All Together: Fish Kill in Riverwood--Who Pays?

Thus, the approaches to the subject of chemistry are markedly different. As the traditional text states, "the central theme of the text is the basic principle that the properties of matter are a consequence of the structure of matter." The ChemCom text "uses chemical concepts to help you understand the chemistry behind some important societal issues."

Chemistry materials

This section considers the basic "shopping list" for an introductory high school chemistry class. Information came from professional and academic literature, from our mail surveys, and from our field visits. As with physics, there are no formal state specifications for curriculum or equipment in chemistry, but LOEO did use technical assistance materials prepared by the Ohio Department of Education.

High school chemistry teachers using both traditional and ChemCom curricula were likely to list as basic equipment needs such items as pH meters, glassware, balances, chemicals, and "more of everything." College professors that were interviewed stated that the top three equipment pieces that students should be familiar with are basic glassware, Bunsen burners, and spectrophotometers.

Appendix II-B shows a list of instructional equipment that appears in the teacher's editions of both a traditional chemistry text and the ChemCom text. It is therefore not a complete list for either curriculum. We used it only to form a general idea of basic equipment needs and availability. In our site visits, we looked for these items, or close substitutes, in every high school chemistry department.

High school chemistry teachers believed they could teach a number of key topics more effectively if they had additional materials or newer equipment, including computers. Organic chemistry, work with pH meters, and electrochemistry were the most frequently mentioned topics. College instructors agreed that students would do better in postsecondary chemistry if they had experience with pH meters and spectrophotometers, as well as laboratory basics such as Bunsen burners and glassware. Exhibit II-2 shows the pieces of equipment that were most commonly cited on the high school teachers' "wish list."

Exhibit II-2

Chemistry Wish List

EQUIPMENT	NUMBER OF RESPONSES
Electronic balances	47
Computers and software	35
pH meters	27
Spectrophotometers	28
Better lab facilities	19
Fume hoods	12

College chemistry instructors were very likely to emphasize the need for understanding theory and proficiency in math, even to the exclusion of familiarity with up-to-the-minute equipment. We interviewed professors from 12 colleges and universities; none said that familiarity with lab equipment alone was an important predictor of success in a college-level course. As the chairman of one university chemistry department stated, "There is such great diversity (among students' high school education) that we start with the assumption that they aren't familiar with lab equipment." Math skills were overwhelmingly considered the best predictor of success.

As with physics, college students interviewed had come primarily from traditional high school chemistry backgrounds. Most of the 45 we interviewed said they were adequately prepared in terms of training on equipment. However, among those interviewed, a number of students made suggestions of equipment which would have improved their college preparation. The most common comment was that the equipment and some of the chemicals were outdated.

Computers in Physics and Chemistry Instruction

Very few organizations, nonprofit or commercial, government or private, would consider a modernization or upgrading project without examining the role computers play in their day-to-day operation. Adults working in technological or scientific industry use computers in many phases of their work, from simple compilation of raw data to the most complex calculations. These industries do not begin by asking whether they will use computers, but rather how much capacity is needed, what new software is available, and how a new system will be integrated with their current systems.

There is general agreement that computers could play a much larger role than they now do in teaching science. Many demonstra-

tions and experiments can be replicated with a high degree of realism on a computer without purchasing expensive single-purpose equipment. In addition, demonstrations or experiments that would be dangerous in real life can be performed safely on a computer--an explosion depicted on a computer screen injures no one.

Issues in computer use

Besides the direct instructional benefit, wider use of computers in high school chemistry and physics classes would have other advantages. To the extent that computers can be used to perform extensive mathematical calculations, for example, they can make science courses less forbidding to students who may traditionally have avoided them.

More basically, all students are likely to benefit from as much exposure to computers as a school can arrange. In an age when carburetors are replaced by microchips, it is not only college-bound students who must be familiar with this technology.

We were told by some high school teachers that there did not seem to be a broad enough supply of high-quality instructional software for high school physics and chemistry. At least one physics teacher said he had to write his own programs, so his use of computers was limited by the amount of time he had available for programming. Teachers responding to our survey listed about 20 different software packages they used, but LOEO did not look into their quality, price, or availability. However, we believe that if there is a large enough demand, commercial software houses will see that useful and affordable programs are written and marketed.

Conclusions and Recommendations

The methods LOEO used to identify basic pieces of instructional equipment were adequate for the purpose of this study--that is, to give the General Assembly a preliminary idea of what equipment is needed and what is available. However, this method does not yield an authoritative "shopping list" for any school or district. That list would depend on the particular curriculum and textbook selected.

State standards

Although there are not now any state specifications for chemistry or physics curriculum or equipment, the Ohio Board of Education has recently named a Commission on Mathematics and Science Education charged with recommending improvements in math and science teaching. One such improvement may be a suggested model science curriculum, similar to those already in place for language arts and mathematics. A model curriculum would presumably include at least a minimum equipment list.

By suggesting the development of model curricula for physics and chemistry, the LOEO is not necessarily recommending that these

courses be included as a part of the competency-based education program of the Minimum Standards for Elementary and Secondary Schools. Rather, we are encouraging the Ohio Department of Education to offer an exemplary model for a science curriculum which also would include a list of the equipment and materials needed to support instruction in high school chemistry and physics.

LOEO recommends that:

* **the General Assembly request the Ohio Department of Education to adopt model curricula with minimum equipment lists for at least high school physics and chemistry.**

Specific equipment requests

LOEO found that in many cases the most expensive, up-to-date equipment may not be strictly necessary for the teaching of a particular principle of physics or chemistry. However, more modern equipment may have some advantages in attracting students into chemistry and physics classes, or in ease of operation, or in safety features.

Nonetheless, older equipment can still serve, to some extent, especially since college faculty agreed that familiarity with particular pieces of equipment is not the most important factor determining a student's success in postsecondary science courses. In addition, trying to keep up to the minute with every piece of equipment can be extremely expensive, since technology is advancing so rapidly.

LOEO recommends that:

* **each district and school study its existing inventory of science teaching supplies and equipment, and then develop and formally adopt a realistic acquisition and replacement schedule. Such a schedule should balance the cost of items with the availability of substitutes. Districts should be able to call upon the Ohio Department of Education for assistance in developing their acquisition and replacement schedules.**

Computers

Computers can--indeed, probably must--play a key role in science instruction in Ohio public schools. Computers can:

* replace many pieces of single-purpose experimental and demonstration equipment;
* broaden the range of experiments and demonstrations that can be performed in the classroom;
* provide students with experience in a technology with which they must become familiar; and
* help to attract students to science courses.

LOEO recommends that:

* **each district and school study its current use of computers in high school science instruction and prepare a plan for expanding the role of computers. Use of computers should be a key consideration in developing the replacement schedule recommended above.**

CHAPTER III

WHAT MATERIALS ARE AVAILABLE?

This chapter describes the supplies and equipment actually available in Ohio high school science classrooms, in light of the equipment needs discussed in Chapter II. Information for this chapter was derived primarily from visits to ten high schools in eight districts around Ohio, and from our mail surveys.

Findings

There are noticeable disparities across and within districts as to availability of physics and chemistry equipment. Some of these differences are due to preferences, and some are due to budget limitations. Classroom teachers show considerable ingenuity in teaching around deficiencies (many report buying materials with their own money).

Results

The most impressive observation LOEO made in its field visits was that good teachers found ways to be effective even when confronted with shortages of supplies and equipment. If a particular item was not available, teachers made do with a substitute; if no materials at all were available for a topic, teachers spent more time on other topics.

The average chemistry teacher we interviewed had been teaching more than 12 years, and the average physics teacher more than 10. As one instructor observed, "A teacher with seven or eight years of experience would be more likely to present an adequate program with limited resources than would a new teacher," but teachers of all skill levels could do a better job with an adequate supply of materials.

One example of the importance of the individual teacher was found at Fayetteville High School (Brown County). The district had the lowest available financial resources per student among those we visited. Instruction followed the traditional model, and lab furnishings were sparse. Nonetheless, five students--all female--from Fayetteville participated in the state science fair in 1990.

Perhaps because their high school teachers were able to teach around supply and equipment shortages, most of the college students we interviewed felt satisfied with their preparation in high school

even though many were aware of the deficiencies. Exhibit III-1 shows the responses of these 45 students to the question, "Did you feel that your high school science classes prepared you for college science classes?"

Exhibit III-1

Student Alumni Interviews

QUESTION RESPONSES	NUMBER RESPONDING
Felt better prepared than others	5
Yes, felt as well prepared as others	27
No, did not feel prepared	3
Had taken no college science	9
Not sure	1

Differences across districts

There were considerable differences in the amount and type of supplies and equipment available to chemistry and physics teachers across school districts. For example, in one large school visited by LOEO, the laboratory facilities lacked adequate equipment, especially in physics. There has been no budget allocation for equipment in the last three years. Physics equipment was extremely limited, even compared to the same school's chemistry program. In physics, adequate supplies were found only for items that were either very durable or very inexpensive. Moderately priced items, if present, were broken and useless. The control knobs of the oscilloscopes were missing, the generators for ripple tanks did not generate, and the tanks leaked. There was an accelerometer, won as a prize by the teacher at a teachers' convention. The physics teacher had written computer software for students to use. However, she needed to reserve computer time two months in advance of expected use.

This contrasts sharply with a school of similar size in a different district. In that school, three chemistry labs have sufficient equipment to allow second-year chemistry students to take a laboratory class in which they do advanced industry-level work.

Differences we observed across districts did not depend entirely on the wealth of the district. One district with a large

tax base supplied only the minimum in laboratory equipment to its science teacher. On the other hand, Southwestern City School District is ranked in the middle of the schools used in this study according to expenditure per pupil and valuation per pupil. Nonetheless, the head of the science department at Southwestern's Grove City High School uses grants received from outside the school district to augment his budget. This has resulted in several very well-equipped chemistry laboratories, a multitude of special opportunities for his students, and supplies to offer innovative programs.

Similar efforts are being made in other Ohio schools. For example, Stark County Local School System has formed The Council for Excellence in Mathematics and Science, a cooperative project of senior executives from Stark County's business community and area educators. Essential to the implementation of the Council's programs was the securing of private foundation support and grants from state and federal sources.

Differences within districts

In each of two urban districts we visited two high schools, selected by the district offices to represent opposite ends of the demographic spectrum in terms of their student bodies. In each we found noteworthy disparities, although the differences were more marked in one of the districts.

The better-off high school in that district boasted a "Super Lab," which was well equipped with up-to-date supplies. Other labs in that school had at least adequate supplies, so that students could perform basic laboratory procedures and experiments alone or in small groups, instead of watching teachers do demonstrations. A markedly different situation was found at the other school in the same district. The chemistry lab there had only one complete set of glassware for an entire class. Burettes, beakers, test tubes, and pipettes were all shared among large numbers of students. Individual students' lab drawers were empty.

Differences between chemistry and physics

Differences we observed between chemistry and physics seemed to be related more to local conditions than to systematic statewide tendencies. Not only does equipment vary greatly from high school to high school, a school with superb facilities for its chemistry programs may provide merely adequate physics facilities. Several schools we visited supplied substantially more equipment for their chemistry programs than for their physics laboratories.

Chemistry teachers were more likely to report that they had adequate materials. This may be the case because chemistry uses fewer pieces of relatively expensive equipment and more relatively inexpensive disposable supplies. In response to the survey question, "Do you have enough basic equipment and expendable supplies to allow students to work alone or in small groups (2-4

students)?" 89.4 percent of chemistry teachers said Yes, but only 63.6 percent of physics teachers said Yes. In other words, more than a third of physics teachers felt they lacked basic equipment and supplies.

Responses to our survey suggest that the majority of schools educating Ohio's future technicians and scientists do not use what has become a workplace necessity. Among chemistry teachers responding to our survey, 61.6 percent do not use computers in any capacity in their classrooms; among physics teachers, 55.6 percent do not. These percentages do not indicate a lack of desire on the part of many teachers to have computers and appropriate software. Indeed, when asked what three pieces of equipment physics teachers would most like to have, "computers" was the most frequent response. Among chemistry teachers, computers were the second most requested item, after electronic balances.

Many teachers who currently use computers wish they had more software as well as more computers. One teacher (who had six computers, as well as a long list of software) stated that with proper software packages, much of his physics equipment could be made obsolete. The same teacher stated that computers were not being used in place of traditional laboratory procedures, rather to augment them. Equipment is available that can allow the computer to be used in place of oscilloscopes, electrical measurement devices, and many types of monitoring equipment.

Not all high school science teachers are enamored with the idea of computers. At one site visit, a teacher stated she did not use computers in her classroom because she was not computer literate. A teacher from a different school system stated he opposed the use of computers in science classrooms because he felt they were not an adequate substitute for primary instruction. (In his school, computers were available in English Writing Centers and in math labs, but were unavailable to science classes.) At a third school, a physics teacher had collected or written software, but the only computer available to her students had to be reserved two months in advance.

During LOEO's interviews of college science professors, computer literacy was mentioned as a necessity or at least a desired skill by several professors. Physics faculty at one university specifically noted that most college-level lab work requires computer skills. They felt that an entering freshman who tests out of introductory physics in college must have good computer skills.

Conclusions and Recommendations

Supply and equipment shortages are affecting the ability of high school science teachers to do as thorough a job as many would like in presenting all the topics in the curriculum to their students. Teachers are generally doing a good job of coping with

these shortages; and, as noted in Chapter II, substitutions for some items are possible.

Differences within districts

Within-district differences such as LOEO observed in at least one city should receive special attention. Model state curricula would presumably reduce this disparity.

LOEO recommends that:

* **even in the absence of state specifications for equipment, every district ensure that all high schools have basic instructional materials before providing more advanced or modern equipment to other high schools in the district.**

Sources of supplies and equipment

Some districts are actively pursuing foundation and governmental grants for new or replacement instructional supplies and equipment; others are actively seeking donations of such goods from private companies. Basic instructional supplies and equipment should be purchased with local district funds. Private contributions or special grants, however, can be a good source of enhanced or updated materials.

LOEO recommends that:

* **after each school and district has prepared its acquisition and replacement schedule recommended in Chapter II, it identify enhancement or supplementary items for which grants or donations would be appropriate and may be available. Local educators could then actively pursue grants or donations for those items; and**

* **the General Assembly request the Ohio Department of Education to identify any state laws or regulations that might impede grants and donations from taking place. These may include not only tax laws, but purchasing requirements, environmental regulations, and any other state restrictions affecting the movement of goods or money from foundations or private companies to Ohio public schools.**

CHAPTER IV

RELATED RESOURCES

For any academic course, some supporting resources need to be available. For instance, the school library should acquire books and subscribe to periodicals appropriate to the students' level that can provide supplementary information to satisfy either research assignments or personal curiosity about the subject.

For science courses with a laboratory component, these related resources also include supplies for prevention and treatment of injury, and for storage and disposal of possibly hazardous materials. This chapter considers those issues, using information gathered from mail surveys and field visits. The chapter concludes with brief discussions of science education issues not directly related to supplies and equipment, that emerged as important topics during this study.

Findings

Library holdings around the state appear to be adequate. There is a need for more attention to both safety equipment and hazardous materials handling.

Library Holdings

In our visits and surveys, we asked science teachers whether current science books, journals, and magazines were available at the school library. During our site visits, we examined the periodicals available in the school library.

Combining the information from visits and surveys, LOEO concludes that school libraries seem to be providing generally adequate support for chemistry and physics instruction. Among physics teachers, 85 percent said libraries had current materials; among chemistry teachers, the figure was 88.6 percent. There were no significant differences among urban, rural, and suburban schools.

Safety Equipment

In physics classes the safety needs are not as extensive as in chemistry classes. The major safety features suggested for the physics lab are a first aid kit, a fire extinguisher, a fire blanket, a portable eyewash bottle, and accessible shut-off valves

and switches for gas, water, and electricity. For chemistry labs, this equipment needs to be supplemented by safety showers and ventilation equipment such as fans and fume hoods.

Appendix IV-A shows a price list of safety equipment for the physics and chemistry labs. Suggested retail prices were obtained from the supplier's catalog.

Availability

Information obtained from our field visits and surveys indicates that most physics labs have adequate safety equipment or access to equipment in adjacent chemistry labs. In most cases, however, the responsibility for safety checks and inspections is left up to the individual teacher. Occasionally, fire extinguishers are examined by the local fire department. Maintenance and repairs are usually performed when requested. In several schools, gas jets and the water supply to student workstations had been shut off due to leaks.

Older laboratory buildings often have inadequate ventilation systems. In addition, fume hoods require special attention, but cannot be expected to totally compensate for a poor overall ventilation design in a laboratory. Teachers report that laboratories have had to relocate in the building in order to provide externally vented fume hoods. Teachers at one school said they had been ordered by the Environmental Protection Agency (EPA) to shut down the school's fume hood.

At least 29 percent of chemistry teachers surveyed said they did not have adequate safety equipment. The most requested safety items were "better ventilation," fume hoods, eyewash and safety shower facilities, and containers for storing hazardous chemicals (see Appendix IV-B).

With increased awareness of safety needs, the cost of enhanced safety equipment may deter some schools from acquiring what they need. At one school, the chemistry teacher pointed out a number of pieces of safety equipment that had been donated to the school; he suggested that the equipment might not have been available otherwise.

Safe working practices and procedures are closely related to the design of safe laboratories. In all the schools we visited, students are instructed and tested on lab safety techniques. However, at one school we observed a lab in which students performed an oxidation-reduction experiment. Although the teacher advised the students to wear aprons and goggles, less than half wore goggles; most did wear their aprons.

Recommendations

Everyone we consulted agreed that the laboratory experience is essential to effective learning in chemistry and physics. However, experiments and demonstrations have inherent risks, and not all schools are adequately addressing these risks.

LOEO recommends that:

* **safety needs be addressed and given the highest priority as schools and districts prepare the materials acquisition and replacement schedules described in Chapter II;**

* **the General Assembly instruct the Ohio Department of Education to include safety equipment and procedures in its model curriculum for science instruction; and**

* **each district ensure that each high school's need for safety equipment and procedures is continually assessed by someone other than classroom teachers. State and local fire and building officials should be able to provide advice and assistance with this.**

Chemical Storage and Disposal

Especially in chemistry, materials are used that are or can become dangerous. Schools therefore bear the responsibility for providing safe storage areas for chemicals, for ensuring that chemicals are discarded before they become dangerously unstable, and that hazardous chemicals are disposed of safely. Facilities for storing and disposing of hazardous waste were frequently requested by high schools. During this study it became clear that the inadequate storage, hauling, and disposal of chemicals is a significant problem in Ohio schools.

Observations

Seven of the ten schools we visited and almost half of the 123 responding to our survey reported inadequate storage or disposal of chemicals. This safety problem is compounded by the fact that 66 percent of the respondents are without a dated inventory method for chemicals.

One chemistry teacher stated that many of the chemicals available for laboratory work in his school are "leftovers from the Sputnik years." Another said that many of their chemicals are also

outdated and cannot or will not be used in any experiment because of the potential hazard. The problem, however, is that the schools reported they have no way to dispose of the chemicals, as many of these substances cannot be discarded in the trash or poured down the drain. Some chemicals can only be transported by an approved hauler, whose services are likely to be expensive.

Among high schools in our study, 21 percent reported having no method at all for disposing of chemicals. An additional problem exists for those schools who store their hazardous or used chemicals in lieu of disposal. Some of the schools we visited stated that although they have storage for their chemicals, storage areas are not properly ventilated.

Survey respondents stated that they need various items to enable them to dispose of dangerous chemicals, including:

* disposal method and facilities,

* adequate storage cabinets, and

* separate storage tanks.

According to an official of the EPA, many Ohio schools are likely to be in violation of the hazardous waste laws. There are federal and state laws and rules and training required by the Occupational Safety and Health Administration (OSHA) regarding the storage of chemicals, and handling and disposal of waste. However, "the word is not getting out to the schools, especially to the vocational schools," he said. "There are problems sitting there just waiting to happen." Although many of the schools are classified only as small quantity waste generators, there are many regulations with which they are to comply.

Recommendations

Some chemicals have always been known to be dangerous, while the dangers of others have been more recently discovered. At the same time, society has become more aware of the need to dispose of all kinds of waste material more responsibly; usually this also means more expensively. Schools must ensure that safe facilities and procedures are in place for storing and disposing of chemicals that are or can become dangerous.

LOEO recommends that:

* the General Assembly immediately require the Ohio Department of Education to adopt a policy which assures adherence to the Ohio hazardous waste rules and Ohio EPA procedures governing storage and disposal of hazardous chemicals. School districts should ascertain that their inventory and storage of chemicals is in compliance with OSHA and EPA requirements;

* the Ohio Department of Education, in consultation with the Ohio EPA and other appropriate state agencies, determine whether a short-term state program is needed to aid local schools in disposing of current supplies of hazardous materials; and

* each district have procedures requiring teachers and principals to determine whether substitute materials or computer simulation can demonstrate a principle without the need for hazardous chemicals.

Additional Issues

This section concerns three issues--curriculum choice, teacher training, and student fees--which are related to science education but only indirectly to supplies and equipment. These issues came to LOEO's attention at various times during this study, and may be the topics of future studies. They are included here only for discussion; this section does not contain any conclusions or recommendations.

Curriculum

LOEO did not study the merits or effectiveness of the ChemCom or Conceptual Physics curricula. However, both are described as being structured in a way that engages the interest of all students by making science relevant to everyday life. Both curricula are also intended to ensure adequate preparation even for students who plan to concentrate in science during their postsecondary careers.

For students planning on taking science courses in college, the most important preparation is a background in mathematics, according to the physics and chemistry professors interviewed for this study. As a result, students preparing for college need to concentrate on mathematics as well as science when choosing their high school courses.

Both the Conceptual Physics and ChemCom curricula are substantially more effective if teachers receive special training, and perhaps only if teachers have personal attitudes and orientations that are amenable to the approach these curricula represent.

Teacher training

Although we did not specifically seek evidence for this, it appears--unsurprisingly--that teachers are more effective in subjects where they have not only knowledge but also interest. An instructor can be certified to teach a subject without necessarily keeping current on either substantive information or teaching techniques. In areas of teacher shortage, such as science and mathematics, this can impair the quality of instruction students receive.

At one high school we visited, for example, physics classes had been assigned to an individual whose primary interest was mathematics and computer science. The teacher seemed enthusiastic about teaching physics, but nevertheless had attended in-service training workshops in math and computers, and none in physics.

Even where a teacher is up-to-date on subject and methods, of course, the teacher's own interests and skills will likely determine which program elements receive the most attention. A person who is primarily interested in chemistry but who also teaches physics, for instance, will tend to know more about the materials needs of the chemistry program than those of the physics classes. One student surveyed explained that in high school her physics teacher was a chemistry teacher who had taught physics for only three years and knew only what was in the book. The physics teacher at summer school, who was primarily trained in physics, was the best she ever had.

Schools operate under very real limitations of money and time, so choices obviously must be made about what workshops to go to or what materials to buy. A teacher is not at fault for attending first to matters of interest to the teacher. There may, however, be a role for principals and district officials in ensuring that balance is maintained so that faculty can be kept fully informed in all areas in which they are actively teaching.

Membership in professional organizations can make available a number of teaching materials that would not otherwise be accessible to the schools. Seven of the ten chemistry teachers at the schools we visited belong to a professional chemistry organization. Two of those who do not belong to any such group stated that the reason was the school would not or could not reimburse them for the costs of membership. Over half of the physics teachers at the same high schools gave the same reason for not belonging to any professional organizations.

Lab fees

In 61 percent of the schools responding to our survey, a lab fee was in place for chemistry students. In 64 percent of these schools, a lab fee was required of physics students. Appendix IV-C shows the number and percentage of schools requiring a lab fee in various amounts.

Whether lab fees actually deter students from taking science courses is not addressed by this study. However, charging a lab fee is certainly not a good way to entice students into the sciences.

Twenty-seven schools said they could waive fees for needy chemistry students; 33 schools could waive them for needy physics students. Districts might consider reviewing their fee policies to ensure that fees are not keeping students out of science classes.

As previously stated, these conclusions and recommendations do not necessarily reflect the views of the Committee or any of its members. Facts and explanations contained in this study were generated entirely by the site visits, interviews, and surveys conducted by the LOEO. The pages that follow contain the appendices referred to in the report.

APPENDICES

APPENDIX I-A 1

LEGISLATIVE OFFICE OF EDUCATION OVERSIGHT
77 South High Street, 9th Floor
Columbus, Ohio 43266

PHYSICS PROGRAM SURVEY

Name and city of high school: _____

Your name and title: _____

1. What physics courses are available at this high school?

COURSE	how many sections?	total enrolled
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

2. For the basic physics class:

   a. Approximately what percentage of class time is devoted to laboratory work?

   _____ none
   _____ more than none, but less than 10%
   _____ at least 10%, but less than 40%
   _____ at least 40%, but less than 60%
   _____ 60% or more

   b. What is the total amount of money available every year in your high school to purchase supplies and equipment for physics classes?

   c. What is the cost to a student to take the course?
   (include lab fees, textbook purchases, other costs paid or reimbursed by students)

   d. If there is a cost to students, can it be waived?

   If so, how and for what students?

   e. Do you have enough basic equipment and expendable supplies to allow students to work alone or in small groups (2-4 students)?

   _____ Yes ____ No; please describe what is needed:

f. Are computers used to conduct or simulate experiments?

_____ Yes ____ No

If Yes, please describe the type and number of computers and the software used:

g. What additional topics would you cover, or what topics would you cover in more depth, if you had additional equipment or supplies?

3. Do you have student workstations with access to:

a. gas? _____ Yes ____ No

b. water? _____ Yes ____ No

c. electricity? _____ Yes ____ No

d. How many students share a workstation?

4. Do you have adequate safety equipment?

_____ Yes ____ No; please describe what is needed:

5. Are any of the following in place or budgeted to be installed in your school for the next year?

a. roof antenna: _____ Yes ____ No

b. solar or cosmic ray monitoring device: _____ Yes ____ No

c. weather instruments: _____ Yes ____ No

6. Are current science books, journals and magazines available through the school library? _____ Yes ____ No

7. What three pieces of equipment or kinds of supplies would you like to have? Describe how you would use each.

APPENDIX I-A 2

LEGISLATIVE OFFICE OF EDUCATION OVERSIGHT
77 South High Street
Columbus, Ohio 43266

CHEMISTRY PROGRAM SURVEY

Name and city of high school: _____

Your name and title: _____

1. What chemistry courses are available at this high school?

COURSE	how many sections?	total enrolled
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

2. For the basic chemistry class:

   a. Approximately what percentage of class time is devoted to laboratory work?

   _____ none
   _____ more than none, but less than 10%
   _____ at least 10%, but less than 40%
   _____ at least 40%, but less than 60%
   _____ 60% or more

   b. What is the total amount of money available every year in your high school to purchase supplies and equipment for chemistry classes?

   c. What is the cost to a student to take the course?
   (include lab fees, textbook purchases, other costs paid or reimbursed by students)

   d. If there is a cost to students, can it be waived?

   If so, how and for what students?

   e. Do you have enough basic equipment and expendable supplies to allow students to work alone or in small groups (2-4 students)?

   _____ Yes ____ No; please describe what is needed:

f. Are computers used to conduct or simulate experiments?

____ Yes ____ No

If Yes, please describe the type and number of computers and the software used:

g. What additional topics would you cover, or what topics would you cover in more depth, if you had additional equipment or supplies?

3. Do you have student workstations with access to:

a. gas? ____ Yes ____ No

b. water? ____ Yes ____ No

c. electricity? ____ Yes ____ No

d. How many students share a workstation?

4. Do you have adequate safety equipment?

____ Yes ____ No; please describe what is needed:

5. Does your school have facilities for collecting, storing, and disposing of dangerous chemicals and chemical waste?

____ Yes ____ No; please describe what is needed:

a. Do all chemical containers show a date or age?

____ Yes ____ No

b. How are outdated and unknown chemicals discarded?

6. Are current science books, journals and magazines available through the school library? ____ Yes ____ No

7. What three pieces of equipment or kinds of supplies would you like to have?

Describe how you would use each.

APPENDIX I-B

COLLEGE AND UNIVERSITY PHYSICS FACULTY

Name and title of individual: _____

Name of institution: _____

1. Is there a physics course in your department in which a student could succeed who had no physics in high school?

2. What is the name/course number of the first physics class in which a student who had a year of high school physics would be more likely to succeed?

3. For a student to succeed in that course:

   a. what principles of physics should the student understand?

   b. what mathematical operations should the student be able to perform?

   c. what laboratory equipment should the student be familiar with?

4. What is the name/course number of the first physics class in which a student who had advanced placement or other accelerated high school physics would be more likely to succeed?

   5. For a student to succeed in that course:

   a. what principles of physics should the studentunderstand?

   b. what mathematical operations should the student be able to perform?

   c. what laboratory equipment should the student be familiar with?

6. Of these three factors (physics principles, math understanding, lab capability) which is most important as a predictor of success in college-level physics?

7. How do you determine whether entering students have the appropriate level of skill and knowledge for the courses in which they register? (placement tests; interviews; high school transcripts; no determination is made--students just decide; other)

8. Are you familiar with the Conceptual Physics high school curriculum? If so, what is your opinion of that approach to high school physics?

COLLEGE AND UNIVERSITY CHEMISTRY FACULTY

Name and title of individual: _____

Name of institution: _____

1. Is there a chemistry course in your department in which a student could succeed who had no chemistry in high school?

2. What is the name/course number of the first chemistry class in which a student who had a year of high school chemistry would be more likely to succeed?

3. For a student to succeed in that course:

   a. what principles of chemistry should the student understand?

   b. what mathematical operations should the student be able to perform?

   c. what laboratory equipment should the student be familiar with?

4. What is the name/course number of the first chemistry class in which a student who had advanced placement or other accelerated high school chemistry would be more likely to succeed?

5. For a student to succeed in that course:

   a. what principles of chemistry should the student understand?

   b. what mathematical operations should the student be able to perform?

   c. what laboratory equipment should the student be familiar with?

6. Of these three factors (chemistry principles, math understanding, lab capability) which is most important as a predictor of success in college-level chemistry?

7. How do you determine whether entering students have the appropriate level of skill and knowledge for the courses in which they register? (placement tests; interviews; high school transcripts; no determination is made--students just decide; other)

8. Are you familiar with the Chemistry in the Community high school curriculum?

   If so, what is your opinion of that approach to high school chemistry?

APPENDIX I-C

The following questions were asked of students who had graduated from the high schools we visited. These individuals were contacted at the colleges and universities they now attend. The lists of names were obtained from the high school guidance offices. We explained to the students what our office does, and what we are doing with this study. They were told how we obtained their names, and those who are interested in a copy of the final draft of our study will receive one in the mail.

1. What is your major?
2. What, if any, science courses have you taken in college? Did any of them repeat what you studied in high school?
3. Did you feel prepared?
4. Did you consider them difficult or easy?
5. How well prepared did you feel compared to the other students?
6. Was there any equipment that would have made your high school lab better, or prepared you more for college?
7. Which material from high school do you remember more, the academics in the text, or the hands-on work in the lab?

APPENDIX II-A

Physics Equipment

EQUIPMENT	COST
Accelerometers	$ 32.25
Balances, spring	$ 9.95
Balances, triple beam (electronic)	$ 168.00
Bunsen Burners	$ 16.00
Capillary tubing	$ 34.00
Computer with software	$ 3,200.00
Galvanometers	$ 115.00
Lasers-helium-neon	$ 310.00
Lenses, convex (set of 6)	$ 19.95
Lenses, diverging	$ 25.00
Lever clamps, knife edge	$ 3.50
Magnets, bar	$ 9.55
Magnets, horseshoe (set)	$ 21.50
Mirrors, plane (pkg. of 10)	$ 8.00
Mirrors, concave	$ 5.90
Mirrors, convex	$ 5.90
Oscilloscopes, dual trace	$ 1,190.00
Pendulum apparatus & clamps	$ 33.00
Inclined plane pulley	$ 7.00
Ripple tanks with generators	$ 130.00
Rings (set)	$ 14.75
Ringstands	$ 9.00
Spectroscopes	$ 48.50
Stopwatches	$ 45.00
Thermometers	$ 5.00
Tuning forks	$ 70.00
Tyndall's apparatus (or paraffin balls, heat source)	$ 37.00

APPENDIX II-B

Chemistry Equipment

EQUIPMENT	QUANTITY	COST
Acetic Acid	500 ml	$ 10.50
Barium chloride	500 g	$ 13.65
Copper (II) sulfate pentahydrate	1 kg	$ 21.00
Filter paper (Whatman #1)	box of 1250	$ 35.00
Glassware Set (test tubes, beakers, etc...)		$ 36.65
Hydrochloric Acid	500 ml	$ 10.50
Iodine Crystals	100 g	$ 21.75
Iron (III) Chloride Hexahydrate	2.5 kg	$ 150.00
Litmus paper, red & blue	pkg. of 24 vials-100 strips per vial	$ 6.50
Magnesium ribbon	1 oz.	$ 17.00
Manganese dioxide-powder	100 g	$ 9.00
Manganese dioxide-education reagent	500 g	$ 22.00
Manganese (II) chloride tetrahydrate	500 g	$ 29.75
Potassium thiocynate	500 g	$ 36.00
Sodium nitrate	500 g	$ 6.00
Sulfuric acid (conc.)	1 liter	$ 20.00
Universal indicator	1 liter	$ 25.00
Zinc strips	500 g	$ 23.75
Scale		$ 7.00
Balances	Triple Beam, Weighing Platform, Tare Beam	$ 105.00
Calipers, vernier		$ 7.00

* Prices listed are mainly from the Education Reagent price list.

APPENDIX IV-A

Chemistry/Physics Safety List

EQUIPMENT	COST
Approved fire extinguishers	$ 90.00
Safety Shower	$ 145.00
Eye wash facility (portable)	$ 125.00
Eye wash facility (faucet mounted)	$ 215.00
Externally vented fume hood	$ 2,545.00
Facilities for safe disposal of waste	$ 146.00
Facilities for collection & storage (Acid cabinet)	$ 775.00
Goggles	$ 3.50
Face shields	$ 10.90
Safety glasses	$ 7.50
Rubber gloves (pkg. of 12)	$ 26.00
Aprons	$ 6.50
Lab coats	$ 17.95
Cabinets for volatile, flammable, corrosive or expensive materials	$ 528.00
First aid kit	$ 60.00
Fire blanket	$ 109.00
Portable eyewash bottle	$ 125.00

APPENDIX IV-B

SAFETY EQUIP NEEDS	NUMBER OF SCHOOLS
Safety glasses	2
Safety gloves	1
Shower	17
Eye Wash Unit	10
Better Ventilation	15
Fume Hood (for ventilation)	13
Lab coats	1
Fire Extinquisher	2
Storage Cabinets (espec. for hazardous chemicals)	8
Emergency Lighting	1
Exhaust Fan	3
Telephone	2
Spill Cleanup packages	2
Instrumentation room	1
Chemical Carriers/transporters	1
Demo safety shield	1
Goggle sterilizer	1
Inventory (professional)	1
General "lab safety" equip.	2*

* College faculty stated this item as a need.

DOLLAR AMOUNT OF FEE FOR CHEMISTRY LAB	NUMBER OF SCHOOLS REQUIRING	PERCENTAGE OF TOTAL SCHOOLS RESPONDING
$20--$25	12	11%
$15--$19	11	10%
$10--$14	20	18%
$ 6--$ 9	13	11%
$ 1--$ 5	21	19%
no fee	35	31%

Fewer schools charge lab fees for physics students, and when they do, the fees tend to be smaller.

DOLLAR AMOUNT OF FEE FOR PHYSICS LAB	NUMBER OF SCHOOLS REQUIRING	PERCENTAGE OF TOTAL SCHOOLS RESPONDING
$20--$25	4	4%
$15--$19	10	9%
$10--$14	13	11%
$ 6--$ 9	18	16%
$ 1--$ 5	21	20%
no fee	43	39%

END

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